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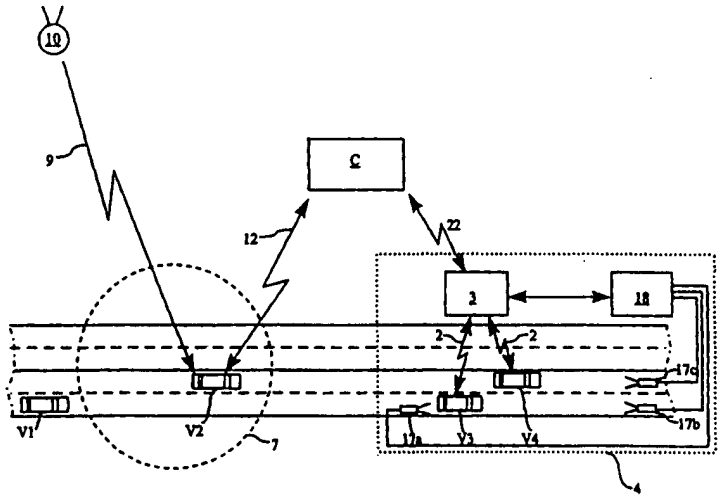

(57) Abstract

A method for automatic debiting of tolls for vehicles (V1–V4) on traffic routes or in traffic zones, the vehicles being equipped with communication devices (1, 11) for communication (12) with a central unit (C) and a roadside unit (3) at a physical toll (4) station. At least one virtual toll charging station (7) is geographically predetermined in relation to the physical station. The vehicle's communication device comprises also a receiver (8) for a signal supplying GNSS system. A first processor (5) reads the position of the vehicle and detects the entry of the vehicle into a virtual toll charging station by comparing the read vehicle position with the positions of the virtual toll charging stations, which data are stored in the vehicle's memory (6), the communication device announcing, via a digital mobile transmitting network to the central unit, that a toll debit transaction is to be executed. The central unit carries out the toll debiting transaction and returns a receipt of the transaction to the vehicle. On entry to the physical toll station the vehicles communication sends, via a communication link to the roadside unit, the receipt as evidence that the correct toll has been paid.

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METHOD FOR AUTOMATIC DEBITING OF TOLLS FOR VEHICLES

TECHNICAL FIELD

The invention presented here concerns a method and a device for the automatic debiting of a toll for a vehicle that uses a zone or zones that are equipped with tolls at the entry to these zones. In this invention a distinction is made between virtual toll stations and physical toll stations, where a toll debiting transaction is carried out at the virtual station, indicated by using a global satellite navigation system, by means of a communication device fitted to the vehicle which communicates, via a digital mobile transmitting network, with the toll debiting system's central system and exchanges information with the central system. At the physical station, the information is then checked so as to determine if a correct debiting of the toll for the vehicle has been performed or if debiting is to be carried out afterwards.

STATE OF THE ART

Automatic stations for debiting of tolls with a variety of designs are known. The document PCT/DE95/00107 describes an example of a toll debiting system of a type mentioned in the introduction. The said document describes a system for debiting of tolls that comprises at least one virtual toll charging station on the traffic route, and in association with the toll charging station a monitoring station, which is physical. A physical toll station is equipped with hardware such as communication units and imaging devices, for example video cameras. A vehicle that is in the virtual toll charging station is able to transmit data via a digital mobile transmitting network to a central unit The virtual toll charging stations are defined at predetermined geographic positions. Aided by a GPS system (Global Positioning System), the position of the vehicle is determined continuously and is compared with the positions of the virtual toll charging stations. If the position of the vehicle coincides with any of the predetermined

virtual toll charging stations, it is indicated by the equipment in the vehicle, after which the vehicle establishes communication via the digital mobile transmitting network. Data which includes toll and charge accounts is transmitted from the vehicle to the central unit . Receipt of payment for the requisite amount is then sent from the central unit to the physical station. The advantage of this technique is that preexisting infrastructure can be utilized, both in this GPS system and in the GSM technique for the digital mobile transmitting network. However, investments in roadside equipment will be required. A further very important advantage is that sufficient time can be allowed for data information exchange between the vehicles equipment and the central unit, so that all transmission can be achieved without capacity problems in computer power or communication. This normally presents difficulties when all the information in existing systems is transmitted within an area consisting of the communication zone of one physical toll station. Moreover, using this method it is possible to separate, both in time and space, debiting of tolls and monitoring of correct payment of charges by vehicles.

A drawback associated with the device described in PCT/DE95/00107 is that the receipt of payment is sent from the central unit to the physical toll station, which means that large amounts of data have to be sent out and be accessible at each physical toll station within a specified area, since at the point of time of payment it is not clear which physical toll station will be subsequently passed. In addition large storage and search capacities are required for computers in the physical toll station. There is no direct communication between the vehicle and the physical toll station, which means that correlation between the identity of the vehicle and receipt is missing.

Document PCT/GB95/00198 describes a further example of a device for automatic debiting of tolls for vehicles where GSM technique is used. In the said document the emphasis is on performing debiting of tolls while preserving the anonymity of the vehicle. This is achieved by means of a vehicle identifier,

fitted to the toll charging station, which identifies a communication device on the vehicle or identifies a vehicle carrying an electronic purse designed for debiting of tolls. The system is also provided with devices that temporarily correlate the vehicle identifier with an identifier for the electronic purse. Furthermore, the system is designed in such a way that the vehicle identifier is not used if the toll debiting transaction is correctly carried out, or that the purse identifier is not used if the toll debiting transaction is not executed satisfactorily. The document also states that the communication device may be a GSM transmitter/receiver. However, there is no description of any type of virtual debiting system. This implies that with this method it is not possible to carry out a toll debiting transaction in advance or to assign the respective vehicles a receipt for payment made before the physical toll station is passed. Hence, the requirement that all communication and identification of the various units must be performed during the time that is available, that is to say, when the vehicle is in the area of the physical toll station. As a result of the lack of time a problem arises, namely that during the short time available manage to identify the vehicles, execute the transaction and also track vehicles for which a correct debit transaction cannot be carried out, so that these can be debited afterwards.

DESCRIPTION OF INVENTION

According to an aspect of the present invention a method for automatic debiting of tolls for vehicles, as specified in claim 1, is set out.

An advantage of the invention over the known technique is that the digital mobile transmitting network is not loaded to the same extent as for the most closely related technique known. A further advantage is that the same storage and search capacities are not required in the storage units in the physical toll station as with the related known technique described in the introduction.

DESCRIPTION OF FIGURES

Figure 1 illustrates schematically the principle of debiting of tolls according to the aspect of the invention.

Figure 2 shows an example of a configuration of units in vehicles, physical toll station and the central unit of the toll debiting system.

DESCRIPTION OF EMBODIMENTS

A number of different embodiments of the invention are described below with the aid of the figures.

Automatic debiting of tolls for admission of a vehicle to a traffic route or traffic zone requires a supervision system. According to a form of execution of the method and the device for automatic debiting of tolls for vehicles, the supervising device comprises vehicle equipment and a roadside unit. The vehicle equipment comprises:

- a first communication device (1) in the vehicle V1-V4 for local communication (2) with a roadside unit (3) at a physical toll station (4). The first communication device (1) may consist of a transponder for the local communication (2) by means of microwaves, or analogous devices which utilize transmission media other than microwaves, such as ultrasound, light inductive transmission etc. DSRC (Dedicated Short Range Communication), where microwaves are used as the transmission medium, is preferred. Other sources that can be used as transmission media for the local communication link (2) between vehicles V1-V4 and the roadside unit (3) are UWB waves (Ultra Wide Band radio), ultrasound, infrared light, laser or ordinary (visible) light,
- a first processor (5) for calculation and/or subtraction of tolls and for guiding

the communication between the vehicle's inner units and the outside world,

- a storage unit (6) for storage of data, such as user identity, positions of virtual toll charging stations (7), tariffs, etc for calculation of said tolls. The user identity may consist of the vehicle identity, the purse identity or the transponder identity,
- a receiver for GNSS (Global Navigation Satellite System), which may consist of a GPS receiver (8) for reception(9) of signals from navigation satellites (19),
- a transmitter/receiver in a cellular network, CN, usually in the form of a GSM telephone (11), for a central communication (12) with a central unit (C) in the toll debiting system

in addition to, preferably,

- a reader (13) for reading and debiting of smart cards, where a suitable CN unit and reader (13) are integrated in a mobile telephone (15) and that
- these said units in the vehicle communicate between one another using an existing vehicle LAN where communication is via CAN data bus or via ITS bus or via appropriate interfaces (or cables).

The physical toll station (4) comprises

- a roadside unit (3) which has a second communication device (16) for the local communication (2) with a first communication device (1) in one of the aforesaid vehicles V1-V4. The use of DSRC (Dedicated Short Range Communication), where microwaves are utilized as the transmission medium, is preferred. Other sources that can be used as transmission media for the local communication link (2) between vehicles V1-V4 and the roadside unit (3) are UWB waves (Ultra Wide Band radio), ultrasound, infrared light, laser or ordinary light,
- video equipment (17a-17c) as well as suitable lighting equipment for reproduction of characteristic features of the vehicle V1-V4, such as the number plate, and for detection of the vehicle's physical shape, including

necessary image processing equipment (18) with OCR functionality (Optical Character Recognition) for identification of registration number or equivalent features,

- a second processor (19) in the roadside unit (3) for determination of the position of the vehicles V3 and V4 within the physical toll station, based on information from measurements with the aid of
  a) the local communication (2) between the first communication device (1) in the vehicle V3, V4 and the second communication device (16) in the roadside unit (3),
  b) information from the image processing equipment (18) as well as
  c) correlation of the positions obtained from measurements carried out with the help of both communication devices (1, 16) and information from the image processing equipment (18),
- a storage unit (20) in the roadside unit (3) for storage of data relating to positions obtained by the local communication (2) between the first (1) and the second (16) communication device,
- equipment (21) in the roadside unit (3) suitable for transmission (22) of registered data to the central unit (for instance,by GSM, WAN or via optical fibre networks) and
- encrypting equipment for encrypted transmission of data between physical toll station (4) and central unit C.

Encryption in this text includes the notion that the message can be encrypted so as to prevent eavesdropping, but the term encryption is also or alternatively used to mean authenticization, that is to say that to the encrypted message is attached a check total or a digital signature which is used to verify that the message has not been garbled and to verify that the sender is the one stated.

Apart from the above mentioned units, it is assumed that the central unit C includes the necessary equipment in the form of a third processor (23), a central storage unit (24), a SAM (Security Application Module) (25), communication

equipment (26) for the central communication (12) with the vehicles' GSM telephones (11) and with the physical toll station's communication equipment (21), from where transmission (22) of data from the roadside unit (3) to the central unit is effected.

The toll debiting procedure proceeds as follows:

In the vehicle's storage unit is the necessary information, such as tariffs for debiting of tolls and positions of virtual toll charging stations (7,) either prestored or continuously updated via, for example, the GSM network or the RDS-TMC link (Radio Data System - Traffic Message Channel) or alternatively via microwave transmitters or their equivalent.

By way of the vehicle's GPS receiver (8) (or another GNSS receiver) information on the vehicle's position is obtained continuously. When the position of the vehicle coincides with the position of one of the virtual toll charging stations (7), the position of which is stored in the vehicle's storage unit (6), as shown in figure 1 for vehicle V2, the central unit C is contacted from the vehicle's GSM telephone (11) (or another transmitter/ receiver in a cellular network). The determined virtual toll debiting position is located at an appropriate distance before a physical toll station (4) that will subsequently be passed by the vehicle. In the virtual toll charging station (7) the vehicle V1-V4 is debited a toll via, in this example, the GSM network. An encrypted signal is sent from the vehicle V1-V4 to the central unit C with information on at least one transponder identity and a statement of the time. A payment transaction is subsequently carried out by means of the central unit's C processor, which debits a prepaid account associated with the transponder identity or deducts the toll in question based on stored tariffs, in the vehicle's storage unit (6), from a smart card in the vehicle which can communicate via the GSM network. The toll is calculated by the vehicle's processor (5). Alternatively, it is possible to send, from the vehicle, the vehicle identity instead of the transponder identity.

In the vehicle V2 there should be equipment (e.g. MMI) which informs the driver that he has entered a geographically defined zone which consist of a virtual toll charging station (7), and indicates that payment of the toll is to be made. The advantages of this are that the driver is not charged without his knowledge, that it is possible for the driver to decide on the method of payment, for example by means of an account or with a smart card, and lastly that the smart card does not need to be in the reader constantly.

When the central unit's processor (23) registers that the vehicle has correctly paid the toll in question, confirmation, in encrypted form, is sent back via the GSM network as a receipt that the vehicle V1 -V4 carrying the specific transponder identity has been debited with a toll of a certain sum. This means that the vehicle itself carries a receipt that the toll has already been paid before the vehicle V1-V4 drives into a subsequent physical toll station's (4) field. With this procedure the only measure necessary at the physical toll station (4) is to verify that the passing vehicle is debited with a toll which corresponds to the category of the vehicle.

When the vehicle reaches the physical toll station (4) a encrypted signal is sent from the vehicle's communication device (1) to the roadside unit's (3) communication device (16), either at the request of the roadside unit's equipment which includes a transmitter, or continuously within a time interval during which communication (2) can proceed owing to the fact that the range for communication is limited. The signal consists of an encrypted message containing data on the transponder identity, receipt of payment, and preferably information on the category of the vehicle. The last mentioned information can then be used to permit the toll station's (4) video equipment (17a-17c) to check the category of the vehicle. The passage of the vehicle V1-V4 through the physical toll station (4) is monitored using video supervision, by the imaging of the vehicle's identity such as the vehicle's licence plate or other physical

feature, and even by detection of the vehicle's physical shape so as to check the category of vehicle given by the vehicle via the communication link (2) between vehicle V1-V4 and roadside unit (3) as just described. An alternative procedure is to merely image the vehicles for which a correct receipt of toll payment cannot be registered.

Communication between vehicle V1-V4 and the roadside unit (3) contain an input of the vehicle's positions. Analogous position detection is even performed with the help of image processing of the results from video supervision using image processing equipment (18) which communicates with the roadside unit's (3) processor (1) for analysis. By correlating the input positions derived partly from the said communication (2) between vehicle and roadside unit, and partly from the positions determined by the video supervision, with each other, communication (2) with a specific vehicle V1-V4 is linked to the vehicle imaged by the video supervision. This correlation is, with todays technique, highly desirable, as it is not yet possible to maintain a one hundred percent identification of registration numbers by video supervision nor to achieve a one hundred percent functioning of vehicle / roadside communication. If this were possible it would be sufficient to correlate registration number indicated by the vehicle / roadside communication (2) with the registration numbers identified by video supervision. Correlation is desirable in order to avoid the risk of, for example, prohibited manipulation of vehicle data stored in the vehicle equipment.

If it is impossible to link correct debiting of a specific vehicle to a specific video registration, the imaging of that vehicle together with the transponder identity, and a statement of the time and zone is sent to the central unit as a basis for subsequent debiting of a toll. If a correct debiting operation is executed, then images and other information memorized in the roadside unit's memory is erased so as to preserve the integrity of the users.

In the proposed example microwave communication is used between vehicles V1-V4 and roadside unit (3).

An advantage of the described system in comparison with those known at present is that it allows sufficient time for communication of transaction data of varying length. As a result of this, other data can without difficulty be transmitted between the first and the second communication devices during the brief time the microwave link, according to our example, is connected within the physical toll station (4). Furthermore, local image processing of the registered vehicles places only small demands and loads on the communication network between the roadside unit (3) and the central unit C.

An additional advantage of the proposed technique according to the aspect of the invention is that it allows automatic debiting of tolls on multi-lane roads, as well as enabling debiting and execution of the payment transactions to be performed in real time, which contributes to increased anonymity for the users in the system.

CLAIMS

1. A method for automatic debiting of tolls for vehicles (V1-V4) on traffic routes or in traffic zones, where the respective vehicles (V1-V4) are equipped with communication input devices (1,11) for communication (12) with a central unit (C) and for communication (2) with a roadside unit (3) at a physical toll station (4), and where at least one virtual toll charging station (7) is geographically predetermined in relation to the physical station (4), characterized in that the method comprises the steps:
the vehicle's communication device comprises a receiver (11) for a GNSS system, which supplies signals, from which a first processor (5) reads the position of the vehicle (V1-V4) and detects the entry of the vehicle into a virtual toll charging station (7) by comparing the read vehicle position with the positions of the virtual toll charging stations, data on which are stored in a memory (6),
the vehicle's communication device (11) announces, via a digital mobile transmitting network to the central unit (C), that a toll debiting transaction is to be executed,
the central unit (C) carries out the toll debiting transaction for the vehicle (V1-V4)
and returns a receipt of the transaction to the vehicle by its communication device (1, 11),
on entry to the physical toll station (4) the vehicle's communication device (1) sends, via a communication link (2) to the roadside unit (3), the receipt as evidence that the correct toll has been payed.

2. A method according to claim 1, characterized in that in connection with the toll debiting transaction at least one transponder identity and a statement of the time is sent from the vehicle to the central unit.

3. A method according to claim 2, characterized in that in connection with the toll debiting transaction the central unit (C) debits a transponder identity-

associated device containing a sum of money.

4. A method according to claim 1, characterized in that in connection with the toll debiting transaction at least one vehicle identity or purse identity and a statement of the time are sent from the vehicle to the central unit (C).

5. A method according to claim 4, characterized in that in connection with the toll debiting transaction the central unit (C) debits a device associated with the vehicle identity or the purse identity, and containing a sum of money.

6. A method according to claims 1-5, characterized in that the receipt which is sent from the central unit (C) to the vehicle (V1-V4) for storage in the vehicle's memory (6) contains data that identifies the vehicle as well as data on the charge debited to the vehicle.

7. A method according to claim 6, characterized in that the receipt which is sent from the vehicle (V1-V4) to the physical toll station's(4) communication device (16) contains data that identifies the vehicle as well as data on the charge debited to the vehicle.

8. A method according to claim 7, characterized in that the signal that constitutes the receipt is encrypted.

9. A method according to claim 8, characterized in that the signal that constitutes the receipt is encrypted and contains a digital signature and a cryptographic check total.

10. A method according to claim 7, characterized in that the receipt also contains data on the category of the vehicle (V1-V4).

11. A method according to claim 1 or 6, characterized in that the communication between the vehicle (V1-V4) and the central unit (C) is

encrypted.

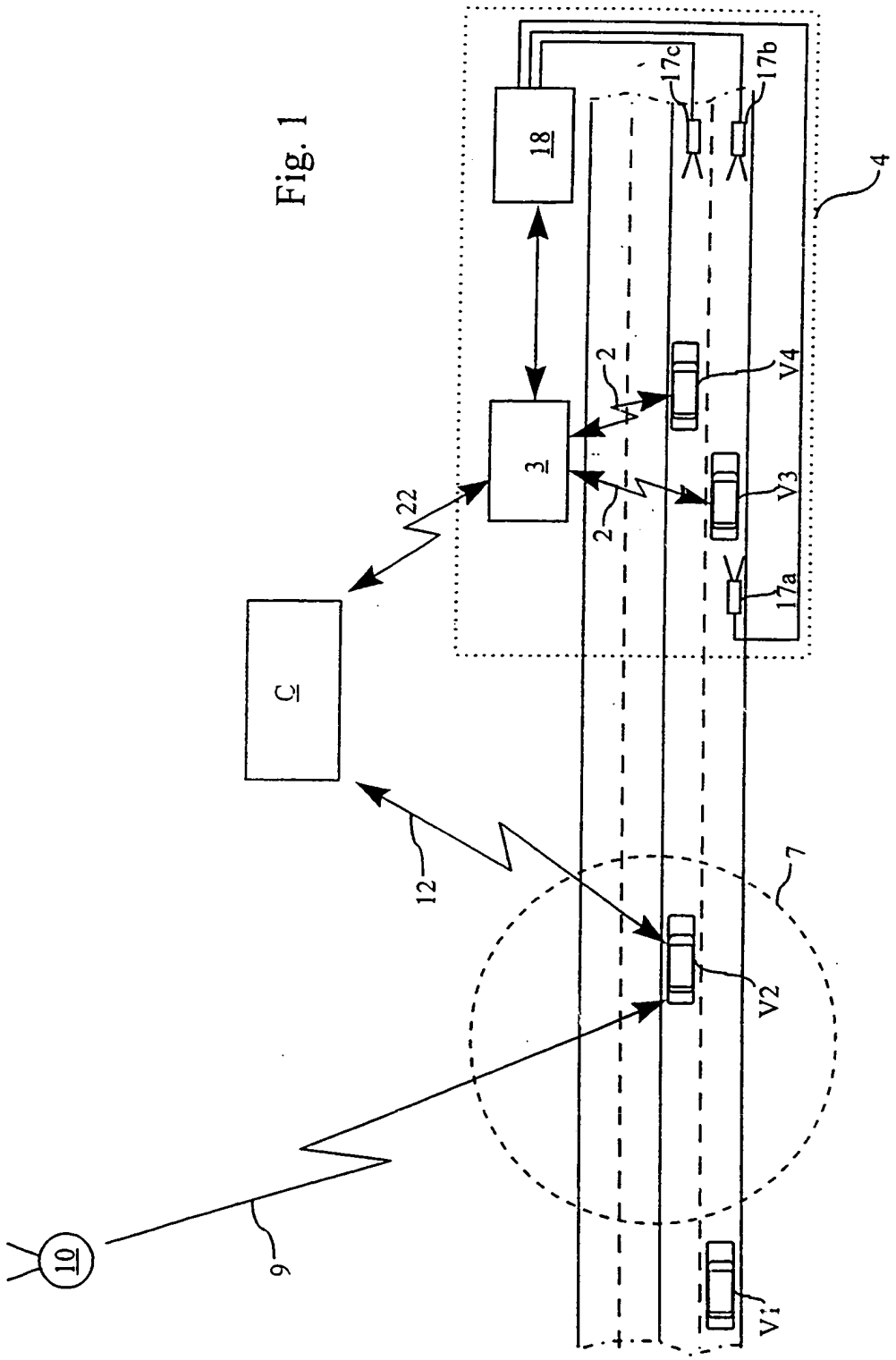
12. A method according to claim 1, characterized in that the respective passing vehicles (V1-V4) are identified in the physical toll station (4) by a correlation between the vehicle identity obtained by imaging and data supplied by the vehicle's receipt.

13. A method according to claim 1, characterized in that communication (12) between the first communication device (1) in a vehicle (V1-V4) and communication equipment (26) in the central unit (C) occurs via a cellular mobile transmitting network such as a GSM network.

14. A method according to claim 1, characterized in that communication (12) between the first communication device (1) in a vehicle (V1-V4) and the second communication device (16) in the physical toll station (4) occurs by means of one of the following carrier media: microwaves, UWB waves, ultrasound, infrared light, laser, ordinary light and inductive transmission.

15. A method according to claim 1, characterized in that in the vehicle's storage unit (6) is stored the requisite information, such as tariffs for debiting of tolls and positions of virtual toll charging stations (7).

Fig. 1



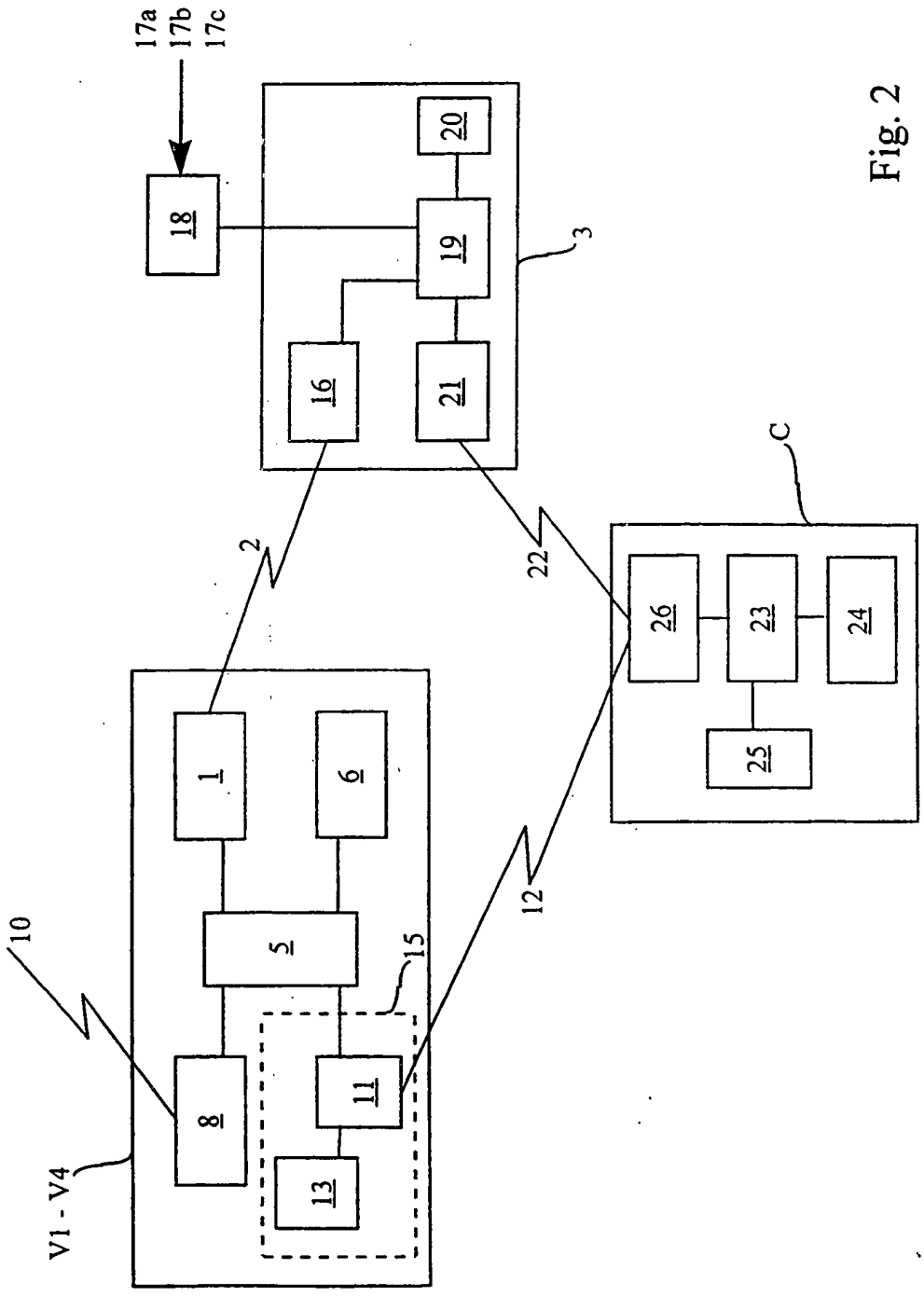

17a
17b
17c
18
20
19
3
16
21
C
2
22
26
23
24
25
1
6
5
15
12
10
8
11
13
V1 - V4

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/02264

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G07B 15/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G07B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9520801 A1 (DETEMOBIL DEUTSCHE TELEKOM MOBILFUNK GMBH), 3 August 1995 (03.08.95), page 10, line 2 - page 13, line 17, figures 1,2 --	1-15
A	US 5490079 A (C.A: SHARPE ET AL.), 6 February 1996 (06.02.96), column 2, line 51 - column 4, line 9, figures 1-3 --	1-15
A	GB 2295476 A (AZTECH SYSTEMS LIMITED), 29 May 1996 (29.05.96), figure 1, abstract --	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 April 1999	29 -04- 1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer Bertil Nordenberg Telephone No. + 46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/99

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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